6.4.3 Retaining Walls

Retaining walls are a specialized structure; therefore, comments and guidelines given in this Section are relevant to retaining wall analysis. This Section provides the basic procedural steps, thought process and initial source of reference and standard forms for a typical geotechnical retaining wall investigation and analyses. Many different wall types are available. See Section 9.4.4 and Section 10.4.12 for retaining wall designs.

The numerous proprietary wall designs require review and comparisons of specific wall design parameters. When proprietary wall designs are suitable for specific site conditions, alternative bid procedures are recommended. To ensure that these alternatives are equal, a review by the Geotechnical Unit prior to the advertisement of the construction contract is required. Designs submitted for approval must contain all calculations and assumptions made by the proprietary wall design. Include with the submittal, copies of any computer programs used. The computer programs must be in a format compatible with government equipment. Major points of comparison will include but are not restricted to the following items:

- design life,
- maximum total and differential settlements,
- maximum stress in wall members,
- magnitude and direction of external loads,
- surface and subsurface drainage required,
- backfill quantity and quality requirements, and
- previous experience with other highway applications.

An overview of the basic retaining wall fundamentals and procedures can be reviewed in the *Forest Service's Retaining Wall Design Guide*. Manufacturers' design charts should only be used as preliminary estimates, and final wall design should be checked by the geotechnical staff. When information is not provided or is unsubstantiated, Rankine analysis and conservative values should be used. See Section 10.4.12 for safety factors and other critical design elements applicable to walls. In addition, consider the following when analyzing retaining wall foundation and backfills:

- do not include material in the upper 1.5 m (5 ft) in front of the wall when evaluating resistance to sliding along the base and overturning;

- the resultant of all forces acting on the wall should fall within the middle third of the base;

- live loads due to temporary construction activities (e.g., materials, equipment) and traffic loading should be in the order of 11 kPa (1.5 lbs/in^2) to 17 kPa (2.5 lbs/in^2);

- avoid backfill material (e.g., silts and clays unless special precautions and analyses are made to account for these materials;

- evaluate expected settlements to ensure that their magnitudes are consistent with the rigidity of the type of wall selected; and

- evaluate subsurface and surface drainage requirements and include any specifications in the geotechnical analysis and recommendation.

The following provides the basic procedures for a typical geotechnical retaining wall investigation:

1. **Initiate Project**. The following applies:

    - Identify available preliminary information (see Exhibit 6.3-A).
    - Determine specific site requirements (e.g., wall location, heights, aesthetic restrictions).

2. **Review Available Geotechnical Data**. The following applies:

    - Review any geotechnical reports and information for project location.
    - Review published information (see Exhibit 6.3-C).
    - Review *Geotechnical Engineering Notebook* retaining wall chapters.
    - Obtain survey information (e.g., cross sections, plans) from the Design Unit.

3. **Plan Field Investigation**. The following applies:

    - Determine drilling requirements (see Exhibit 6.3-E).
    - Review checklists for site investigations (Form 6.4-H) and retaining walls (Form 6.4-N) to identify needed information to be collected.
    - Determine preliminary equipment requirements (see Exhibits 6.3-B, 6.3-D and 6.3-F).
    - Determine site restrictions and revise equipment requirements. A site visit may be required.
    - Develop a preliminary boring and testing plan (see Form 6.3-B).

4. **Plan Sampling and Testing**. The following applies:

    - Determine sampling and testing requirements (see Exhibits 6.3-E, 6.3-G and 6.3-U).
    - Record field information (see Forms 6.3-C, 6.4-C and Exhibits 6.3-N, 6.3-O, 6.3-S, 6.3-T, as applicable).

5. **Summarize Field Data**. The following applies:

    - Review Exhibit 6.3-Q and Form 6.4-H.
    - Review checklists for general report (Form 6.4-G) or site investigation (Form 6.4-H), as appropriate.

6. **Perform Analysis and Write Report**. The following applies:

- Review checklists for retaining walls (Form 6.4-N) and spreadfootings (Form 6.4-K), piles (Form 6.4-L) or drilled shafts (Form 6.4-M), if applicable.
- Provide allowable bearing pressure (Form 6.4-I) and pile capacity (Form 6.4-J), as applicable.
- Write draft report.
- Refer to the General Report Checklist (Form 6.4-G) and the Site Investigation Checklist (Form 6.4-H) to ensure appropriate report content.
- Finalize report.

6.4.4 Pavement Design

The pavement design procedures used by FLH Divisions use empirical data developed from AASHTO road tests that are modified by experience gained from pavements built for use on Federally owned lands. The concepts are based upon procedures presented in the AASHTO *Interim Guide for Design of Pavement Structures*. It is anticipated that the new concepts and procedures presented in the 1993 AASHTO *Guide for Design of Pavement Structures* will eventually be incorporated into the Federal Lands Highway pavement design procedures. Until that time, correlation between the existing procedures and the new procedures presented in the new AASHTO *Manual* is encouraged to establish a database for the purpose of confirming the reliability, standard deviation and changes in serviceability input parameters required by the new procedures.

Pavement designers should familiarize themselves with the DARWIN computer program. This Program incorporates the design procedures provided in the AASHTO *Guide for Design of Pavement Structures* 1993.

Generally, only flexible pavements are built by FLH Divisions and therefore this section will deal primarily with flexible pavement design procedures. Where rigid pavements are required and designed, follow the procedures and guidelines used in the AASHTO *Design of Pavement Structures*.

The following provides the basic procedural steps, initial sources of reference materials and standard forms for a typical pavement design investigation:

1. **Initiate Project**. The following applies:

    Identify available preliminary information (see Exhibit 6.3-A).

    - Obtain project-related restrictions (e.g., costs, aesthetics, environmental) imposed by others by reviewing preliminary project development information.

2. **Review Available Geotechnical Data**. The following applies:

Retaining Wall Checklist

Project: ______________________________

Location: ______________________________

Prepared by: ____________________ **Date:** ____________________

Components	Check Appropriate Box: Yes	No	Not Applicable
1. Does the geotechnical report include recommended soil strength parameters and groundwater elevation for us in computing wall design lateral earth pressures and factor of safety for overturning, sliding and external slope stability?			
2. Does the design lateral earth pressure include the effects of soil backfill strength, slope geometry and surcharge loads?			
3. Has the most suitable and cost-effective wall type(s) been selected for the specific site conditions?			
4. Are reasons given for the choice and/or exclusion of certain wall types (gravity, reinforced soil, tieback, cantilever, bin, gabion, etc.)?			
5. Does wall design provide for and identify minimum acceptable factors of safety against overturning, sliding and external slope stability?			
6. If wall will be placed on compressible foundation soils, is estimated total settlement, differential settlement and time rate of settlement given?			
7. Can selected wall system(s) tolerate the estimated differential settlement?			
8. If special drainage details are needed behind and/or beneath the wall, are recommended details provided in the geotechnical report?			
9. Is proposed to bid alternative wall designs?			
10. Construction considerations:			
a. Are excavating requirements covered (safe slopes for open excavations, need for sheeting or shoring, etc.)?			
b. Fluctuation of groundwater table?			
11. Are recommended contract special provisions provided?			

Form 6.4-N SAMPLE OF RETAINING WALL CHECKLIST

- Review any geotechnical reports and information for project location.

- Review published information (see Exhibit 6.3-C) with emphasis on USDA soil surveys for project site.

- Determine thickness of the existing pavement and identify initial design material properties.

3. **Plan Field Investigation**. The following applies:

   - Determine drilling requirements (see Exhibit 6.3-E).

   - Review the Pavement Design Checklist (Exhibit 6.4-O) to identify needed information to be collected.

   - Determine preliminary equipment requirements (see Exhibits 6.3-A, 6.3-D and 6.3-F).

   - Develop a preliminary boring and testing plan (see Form 6.3-B).

4. **Plan Sampling and Testing**. The following applies:

   - Determine sampling and testing requirements (see Exhibits 6.3-E, 6.3-G, 6.4-D and 6.4-F).

   - Record field information (Forms 6.4-P, 6.4-Q, and Form 6.4-R, as applicable).

5. **Summarize Field Data**. The following applies:

   - Review Exhibits 6.4-F and 6.4-G.

   - Summarize soils and other data as appropriate (see Forms 6.4-D, 6.4-E, 6.4-F and Exhibit 6.4-B).

   - Prepare Exhibit 6.4-F or 6.4-H and 6.4-D or 6.4-E, as applicable.

6. **Perform Analysis and Write Report**. The following applies:

   - Review the pavement design checklist (Form 6.4-O) to ensure all appropriate information is available.

   - Document the pavement design parameters (Exhibits 6.4-H, 6.4-I and Form 6.4-S), as applicable.

   - Write draft report.

   - Refer to the General Report Checklist (Form 6.4-G) and the Site Investigation Checklist (Form 6.4-H) to ensure appropriate report content.

   - Finalize report.

Pavement Design Checklist

Project: ______________________________

Location: ______________________________

Prepared by: ______________________ **Date:** ______________________

Components	Check Appropriate Box		
	Yes	No	Not Applicable
1. Has a visual distress assessment of the existing pavement been made and is summary of results provided?			
2. Has the roughness of the existing pavement surface been measured and are results summarized?			
3. Have deflection tests been made on the existing pavement and the results summarized?			
4. Has a subsection breakdown been provided to group similar existing conditions, pavement structure and expected traffic loads within the project?			
5. Are traffic estimates provided that include total ADT, trucks, and accumulative equivalent 80KN (18,000 lbs)?			
6. Are strength properties and thickness of each of the pavement layers and subsections included?			
7. Is the design method used to develop the pavement alternatives identified and are all inputs used for design clearly summarized?			
8. Are advantages and disadvantages of each alternative provided for the acceptable pavement structures?			
9. Are reasons for recommended pavement structure alternatives clearly stated?			
10. Are construction problems, weather restrictions, water and/or material problems considered?			
11. Are recommended contract specifications provided?			
12. Has a life cycle cost analysis been performed?			

Form 6.4-O SAMPLE OF PAVEMENT DESIGN CHECKLIST

6.4.4.1 New and Reconstructed Pavement Design

The information provided in this Section should be considered a guideline and is subject to revisions and deviation based upon new developments and sound engineering judgment. The design of new flexible pavements requires the following:

1. **Traffic Data Analysis**. Detailed analysis of traffic requires loadometer data and breakdown of annual daily traffic for specific vehicle types and axle arrangements. Detailed examples of the procedures are given in Appendix C.2 of the AASHTO *Interim Guide for Design of Pavement Structures*. This type of information is not often available on FLH roads. Therefore, simplified traffic analysis is often used. Annual Daily Traffic (ADT) is estimated and the estimated percentage of major vehicle types is combined with Equivalent 80 kN (18,000 lbs) Axle Loads (EAL) to determine an EAL/day to represent all traffic data. Typical EAL values for common vehicles are:

   - Automobile — 0.0004,
   - Recreation Vehicle — 0.20,
   - Light Truck — 0.20,
   - Heavy Maintenance Truck — 0.60,
   - Logging Truck — 2.30, and
   - Bus — 0.88

   In lieu of other data, typical values used in traffic analysis for FLH pavements are 20 year design periods and two-percent growth factors and minimum 5 EAL/days.

2. **Existing Soils Strength Determinations**. Existing subgrade soil strengths are evaluated by using the soil support correlation values. Three acceptable methods of obtaining soil support values are listed:

   - three-point (CBR) test,
   - Resilient Modulus (M^r) test, and
   - HVEEM Resistance (R) test.

   The design soil support values can be determined from a percentile evaluation, an average or a minimum value, depending upon the situation and allowable risk of premature or localized pavement distressed areas. However, it is recommended that the 80th percentile and Exhibit 6.4-G be used to determine soil support values. Use the following soil support values and corresponding soil type as a general guide for subgrade soil conditions:

   - Poor soils — 0 – 4,
   - Medium soils — 4 - 6.5, and
   - Good soils — 6.5 – 10

3. **Environmental Data Considerations**. The site-specific environmental data is evaluated by using regional factors. The basic components are precipitation, drainage and elevation. Exhibit 6.4-F may be used to determine a site-specific environmental regional factor.

These factors should be adjusted for other conditions (e.g., seasonal traffic loads, subgrade frost heave potential, subgrade shrink/swell potential).

4. **Construction Material Strengths**. The different construction material strengths are evaluated by using a structural coefficient. The ranges of structural coefficients (SC) for material used on FLH projects are shown in Form 6.4-S.

   For other material types, typical Structural Coefficient (SC) values may be found in the AASHTO *Interim Guide* or may be estimated from Equation 6.4(1):

   $$SC = 0.14 - 0.006(83 - R)$$ (Metric) Equation 6.4(1)

   To Be Provided (US Customary) Equation 6.4(1)

   where:

   R = R-value determined at 2070 kPa (300 psi) exudation pressure (AASHTO T 190).

5. **Serviceability**. Generally, FLH roads should be designed for a terminal serviceability index of 2.0. However, roads with ADT's greater than 500 and/or roads considered primary routes may be designed using a terminal serviceability index of 2.5.

   These elements are combined by using the design charts and procedures provided by Exhibits 6.4-H and 6.4-I. Actual layer thickness is determined by using Form 6.4-S to satisfy the required structural number (SN).

   For new construction, recommended minimum thicknesses of pavement structure materials are the following:

   - asphaltic concrete pavement = 50 mm (2 in), and
   - aggregate base course = 150 mm (6 in).

The information provided here should be considered a guideline and is subject to revisions and deviation based upon new developments and sound engineering judgment and analysis.

Precipitation		Elevation		Drainage	
Millimeters	**Factor (P_f)**	**Meters**	**Factor (E_f)**	**Condition**	**Factor (D_f)**
< 250	0	< 2000	0	Good	0
≥ 250 to <325	0.25	≥ 2000 to <2300	0.25	Fair	0.50
≥ 325 to< 425	0.50	≥ 2300 to <2600	0.50	Poor	1.0
≥ 425 to <600	1.0	≥ 2600 to <2900	1.0	Severe	2.0
≥ 600	1.5	>2900	1.5		

Note: Total Regional Factors (RF) = $P_f + E_f + D_f$

Exhibit 6.4-F REGIONAL FACTOR GUIDELINES FOR PAVEMENT (Metric)

Precipitation		Elevation		Drainage	
Millimeters	**Factor (P_f)**	**Meters**	**Factor (E_f)**	**Condition**	**Factor (D_f)**
		To Be Provided			

Note: Total Regional Factors (RF) = $P_f + E_f + D_f$

Exhibit 6.4-F REGIONAL FACTOR GUIDELINES FOR PAVEMENT (US Customary)

Pavement Bore Log			
Project:	Boring No.:	Date:	Sheet of
Boring Location:	Type of Boring:		
	Inspector:		
Type of Pavement:			

Depth	Description	Comments

Form 6.4-P PAVEMENT BORE LOG

Asphaltic Concrete Pavement Condition Survey*

Project : ____

Beginning Reference Location: ____________________________

Direction: ______________ Logged By: ________________ Date: __________

Station	Left Lane	Right Lane	Station	Left Lane	Right Lane

Key:

Severity	**Code**
High	H
Medium	M
Low	L

Distress Types*	**Code**
Alligator Cracking	1
Block Cracking	2
Lane/Shoulder Dropoff or Heave	3
Lane/Shoulder Joint Separation	4
Longitudinal cracks	5
Patching	6
Pothole	7
Raveling	8
Rutting	9
Transverse Cracks	10
____________________	11
____________________	12

Remarks

* *See Highway Pavement Distress Identification Manual.*

Form 6.4-Q SAMPLE OF ASPHALT CONCRETE PAVEMENT CONDITION SURVEY

Portland Cement Concrete Pavement Condition Survey*

Project Name: ______________________________

Beginning Reference Location: ______________________________

Direction: ______________ Logged by: ______________ Date: __________

Station/Location ______________

1	2	3	4	5	6	7	8	9	10

Faulting ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Remarks

Station/Location ______________

1	2	3	4	5	6	7	8	9	10

Faulting ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Remarks

Station/Location ______________

1	2	3	4	5	6	7	8	9	10

Faulting ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Remarks

**See Highway Pavement Distress Identification Manual*

Form 6.4-R PORTLAND CEMENT CONCRETE PAVEMENT CONDITION SURVEY*

Portland Cement Concrete Pavement Condition Survey (cont)
Instructions

Distress Information

a. Amount of faulting - greater than or equal to 3 mm (0.1 in), 1 m (3 ft) from curb joint.

b. Location and severity of all cracks located from joint -
   L = hairline (less than 2 m (6.5 ft) long - do not survey)
   M = working crack - less 13 mm (0.5 in) fault
   H = greater than 25 mm (1 ft) and/or greater than 13 mm (0.5 in)

Maintenance and Repair

a. Edge drain installations - location of cut areas
   |CUT→ ←CUT|

b. Joint repair due to spalls
   L = less than 75 mm (3 in) from joint
   M = 75 mm (3 in) to 150 mm (6 in) from joint
   H = greater than 150 mm (6 in) from joint

c. Asphalt patch area and location

d. Mudjacking hole locations

General Information

a. Station number locations

b. Marking beginning and ending locations of entrance and exit ramps

c. Location of mainline and overhead bridges, culverts and inlets

d. Location of expansion joints - traverse (slab length)

e. Joint spacing - longitudinal (slab width)

f. Record road grade as uphill (+) or downhill (-)

g. Joint width (nearest 3 mm (0.1 in)) - put in remarks section of survey form

h. Slab dip (¦→ down from profile)

i. Faulting measurement for each joint is to be recorded in the space provided under each joint

j. Notations such as grade, super elevation, grinding and such other information which remain constant for considerable distances need only be noted on the first and last slab on each survey sheet and at its beginning and ending occurrence. The arrow must be included to indicate that the condition is occurring on all slabs and not in the individual slab marked.

Form 6.4-R PORTLAND CEMENT CONCRETE PAVEMENT CONDITION SURVEY*
(Continued)

To Be Provided

Exhibit 6.4-G SOIL SUPPORT CORRELATIONS
(Metric)

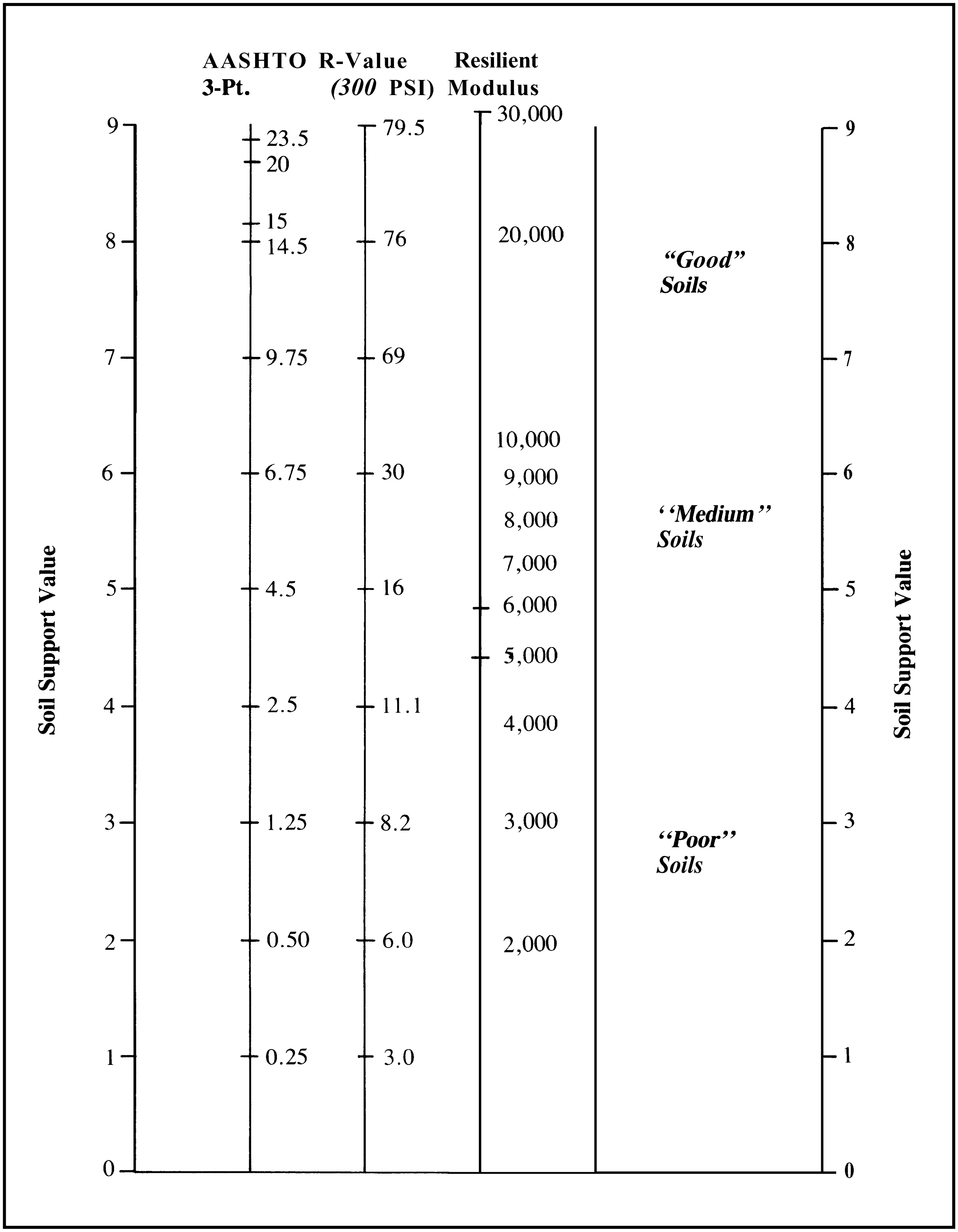
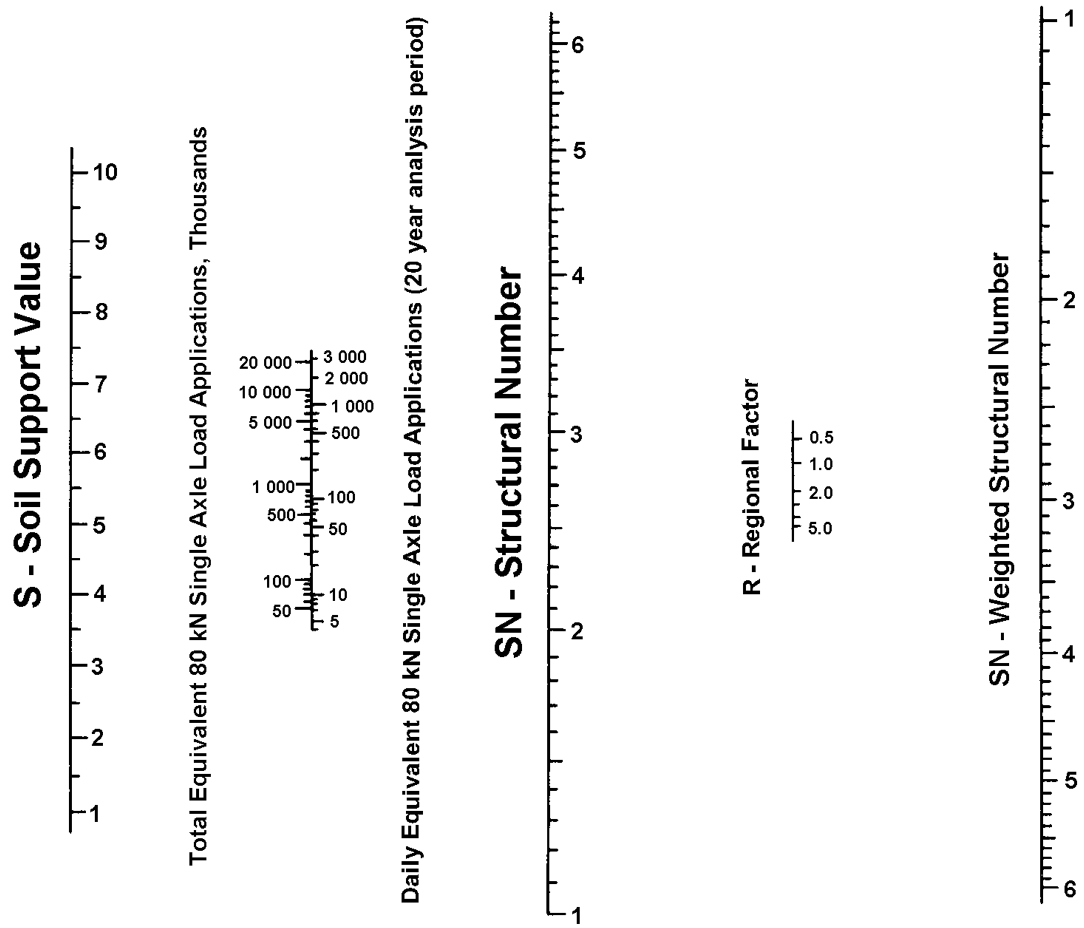


Exhibit 6.4-G SOIL SUPPORT CORRELATIONS (US Customary)



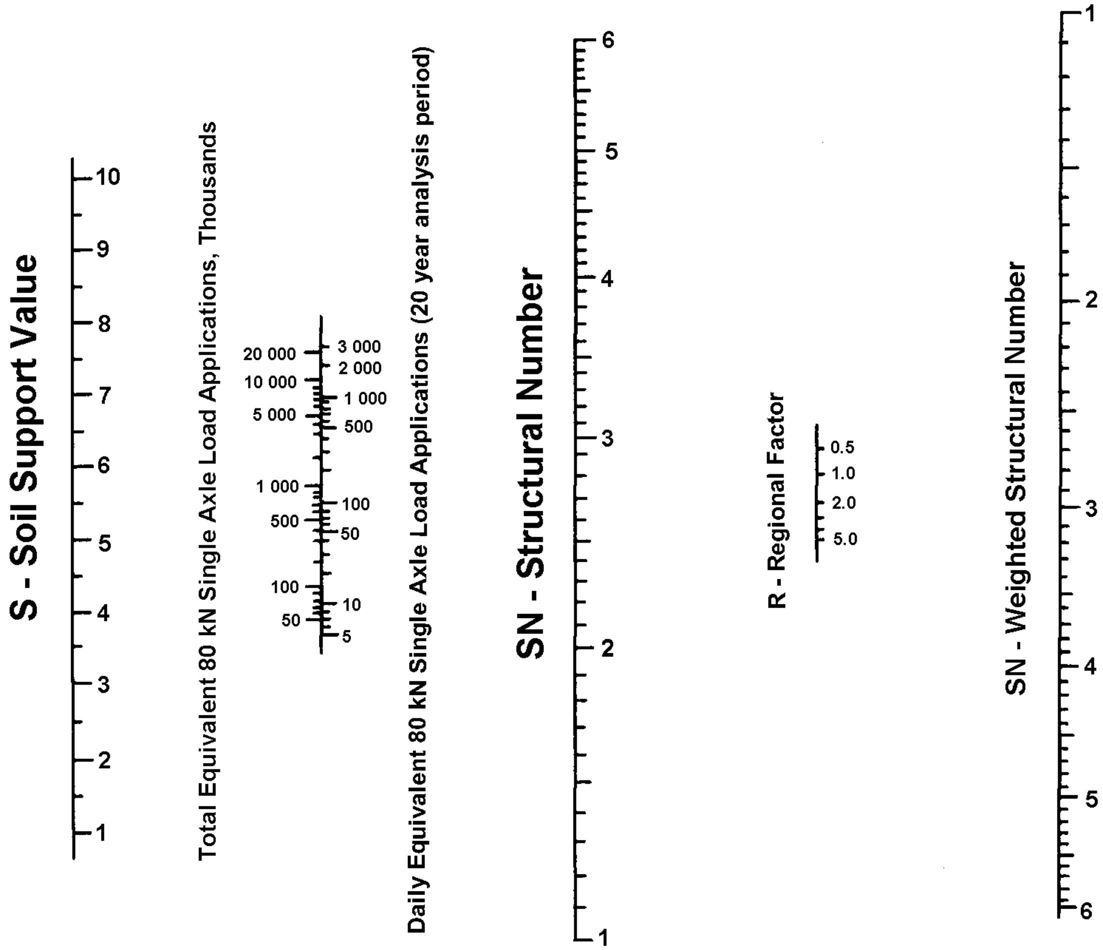
The chart requires two applications of a straightedge for each solution. First, the soil support value of the roadbed soil (on the left scale) and the total or daily equivalent 80 kN single-axle loads for the traffic analysis period (left side of second scale) are used to solve for the unweighted structural number (center scale). This unweighted structural number is used with the selected regional factor (4th scale) to solve for the design SN (right scale) applicable to the total pavement structure. Suitable designs are those whose combinations of materials types and thicknesses satisfy the general equation:

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

Exhibit 6.4-H DESIGN CHART FOR FLEXIBLE – P_t = 2.0 (Metric)

To Be Provided

Exhibit 6.4-H DESIGN CHART FOR FLEXIBLE – P_t = 2.0
(US Customary)



The chart requires two applications of a straightedge for each solution. First, the soil support value of the roadbed soil (on the left scale) and the total or daily equivalent 80kN/ /single-axle loads for the traffic analysis period (left side of second scale) are used to solve for the un-weighted structural number (center scale). This unweighted structural number is used with the selected regional factor (4^{th} scale) to solve for the design SN (right scale) applicable to the total pavement structure. Suitable designs are those whose combinations of materials types and thicknesses satisfy the general equation:

$$SN = a_1D_1 + A_2D_2 + A_3D_3$$

Exhibit 6.4-I DESIGN CHART FOR FLEXIBLE PAVEMENTS – P_t = 2.5 (Metric)

To Be Provided

Exhibit 6.4-I DESIGN CHART FOR FLEXIBLE PAVEMENTS – P_t = 2.5
(US Customary)

Pavement Structure Layer Thickness Worksheet

Project ________________________________ Prepared By:_________________________

Section ______________ From:__________ To:_________________ Date:__________

Traffic Analysis

AADT X DY X 365X DDF X LDF X LF = Total 80kN ESAL Design

____ X _____ X 365X _____ X ___X ____ = _________ Use [ ]

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)
Load Factor (LF) = 80kN Equivalent Load Factor per Vehicle

Regional Factor (RF)

Percipitation (mm/yr) ____________ P_f _____

Average Elev. (m) ______________ E_f ______

Drainage ______________________ D_f _____

Total RF [ ]

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	_______	_________	
Base	_______	________	
Subbase	______	________	

Soil Support Value

Description: ____________________________ Classification: ___________________________

No. Samples Taken: _____________________ Range of Test Values _____________________

Type of Tests: ____________________________ No. of Tests: ______ Design Test Value: _____

Design Soil Support Value [ ]

Design Terminal Serviceability (P_f) = [ ]

Required Structural Number (SN) = [ ]

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design			Alternative #2 Design			Alternative #3 Design		
		SC	Thick.	SN	SC	Thick.	SN	SC	Thick.	SN
	x 10^{-3}									
Seal Coat	0 – 1.97									
Plant Mix Seal	9.84 – 19.68									
Plant Mix Surfacing	13.78 – 17.72									
Road Mix Surfacing	7.87 – 9.84									
Stab. Base Plant Mix	9.84 – 11.81									
Stab. Base Road Mix	5.91 – 7.87									
Stab. Base Emulation	4.72 – 11.02									
Stab. Base Cement	4.72 – 9.45									
Stab. Base Lime	4.72 – 9.45									
Crushed Agg. Base	3.94 – 5.91									
Gravel Base	2.75 – 5.51									
Select Borrow	1.97 – 3.94									
Exist Roadway										
Totals										

Form 6.4-S PAVEMENT STRUCTURE LAYER THICKNESS WORKSHEET (Metric)

Pavement Structure Layer Thickness Worksheet

Project: OR FN 141 Prepared By: M. Symons
Section: 1 From: MP 125 To: MP 130 Date: 1-27-95

Traffic Analysis

AADT X DY X 365X DDF X LDF X LF = Total 80kN ESAL Design

200 X 20 X 365X .5 X 1 X .8 = 584,000 Use $\boxed{600,000}$

AADT = (Present ADT + Future ADT)/2
DY = Number of Design Years (Typ. 20)
DDF = Directional Factor (Typ. .5)
LDF = Lane Distribution Factor (Typ. 1.0)
Load Factor (LF) = 80kN Equivalent Load Factor per Vehicle

Regional Factor (RF)

Percipitation (mm/yr) 500 P_f 1.0
Average Elev. (m) 2400 E_f 0.5
Drainage Poor D_f 1.0

Total RF $\boxed{2.5}$

Existing Pavement Structure

	Material Type	Thickness Range	Strength Range
Surface	BST	25-50mm	None
Base	Gravel	100-200mm	None
Subbase	None	-	

Soil Support Value

Description: Clay Gravel Classification: A-2-4
No. Samples Taken: 8 Range of Test Values 30-50
Type of Tests: R-Value No. of Tests: 6 Design Test Value: 35

Design Soil Support Value $\boxed{6.2}$

Design Terminal Serviceability (P_f) = $\boxed{2.5}$

Required Structural Number (SN) = $\boxed{2.80}$

Pavement Structure Alternatives

Pavement Component	Typical Range of Structural Coefficient (SC)	Alternative #1 Design SC	Alternative #1 Design Thick.	Alternative #1 Design SN	Alternative #2 Design SC	Alternative #2 Design Thick.	Alternative #2 Design SN	Alternative #3 Design SC	Alternative #3 Design Thick.	Alternative #3 Design SN
	x 10^{-3}	x 10^{-3}			x 10^{-3}			x 10^{-3}		
Seal Coat	0 – 1.97									
Plant Mix Seal	9.84 – 19.68									
Plant Mix Surfacing	13.78 – 17.72	13.78	80	1.10	13.78	100	1.38	13.78	120	1.65
Road Mix Surfacing	7.87 – 9.84									
Stab. Base Plant Mix	9.84 – 11.81									
Stab. Base Road Mix	5.91 – 7.87							7.87	150	1.18
Stab. Base Emulation	4.72 – 11.02									
Stab. Base Cement	4.72 – 9.45									
Stab. Base Lime	4.72 – 9.45									
Crushed Agg. Base	3.94 – 5.91	5.51	250	1.38	5.51	275	1.51			
Gravel Base	2.75 – 5.51									
Select Borrow	1.97 – 3.94									
Exist Roadway		3.00	100	0.30	0	0	0	0	0	0
Totals			330 (New)	2.78		375	2.89		270	2.84

Form 6.4-S PAVEMENT STRUCTURE LAYER THICKNESS WORKSHEET
(Continued)

To Be Provided

Form 6.4-S PAVEMENT STRUCTURE LAYER THICKNESS WORKSHEET (US Customary)

6.4.4.2 Pavement Overlay Design

Four different design methods are used to design pavement overlays. These are the minimum thickness, engineering judgment, structural deficiency and deflection based methods. Generally, the method used on any given design problem will be dictated by the information available to the designer. If more than one design method is practical, the overlay should be checked by the other available methods. The following applies:

1. **Minimum Thickness**. Very thin pavement overlays tend to tear and separate from the underlying pavement during construction and are almost impossible to construct. If an overlay is not intended to serve any structural purpose, but only to correct a surface defect in the pavement, no further design is necessary and the overlay can be the minimum thickness. If, however, the overlay will serve a structural purpose, another design method must be used to determine thickness requirements.

   A 50-mm (2-in) lift of asphaltic concrete pavement is normally the minimum depth of overlay for structural improvement. Overlays less than 50 mm (2 in) but no less than 20 mm (0.75 in) may be used under the following conditions:

   - additional structural capacity is not required for the section proposed for resurfacing; and
   - the primary function of the overlay is to improve the surface properties of the roadway (i.e., skid, noise and riding quality adversely affect operational safety characteristics).

2. **Engineering Judgment**. If a designer has extensive experience with pavements that are similar to the one being overlayed, it may be possible to arrive at the required design thickness by applying engineering judgment. While in the hands of an experienced engineer this method can yield good results, it is still little more than an educated guess. Therefore, using engineering judgment as the prime design method should be limited to those projects so small that it is uneconomical to gather the data for a more sophisticated approach. On the other hand, engineering judgment should always be used to check the reasonableness of the results of the more analytical methods.

3. **Structural Deficiency**. The structural deficiency method consists of finding the structural number that would be required of a new pavement to support the design traffic and then subtracting the structural number of the existing pavement from it. The structural deficiency method can be summarized in these two equations:

   $$SNO = SNN - SNE \qquad \text{Equation 6.4(3)}$$
   $$SNO = aODO \qquad \text{Equation 6.4(4)}$$

   where:

   SN_O = Structural number for the proposed overlay
   SN_N = Structural number for a new pavement
   SN_E = Structural number for the existing pavement
   a_O = Layer coefficient for the overlay material
   D_O = Overlay thickness, mm (in)

The structural number (SN_N) required for a new pavement can be computed using the standard pavement design methods. Unfortunately, there is no single, clear-cut way to compute SN_E. There are several semi-empirical methods, but their use must be tempered with good judgment and, when possible, checked against one another. To a large extent, the accuracy of the structural deficiency method is dependent upon the accuracy of SN_E.

4. **Deflection and Mechanistic Based Method**. This method uses dynamic deflection measurements to estimate the condition of the existing pavement and the thickness of the required overlay. The first step in the design process is to take deflection measurements periodically along the roadways to be overlayed. Generally, a measurement is taken every 150 m (500 ft) along the roadway in each traveled lane. The measurements in adjacent lanes should be staggered by 75 m (250 ft) so that the maximum roadway coverage can be achieved.

   These are only guidelines, however, and can be varied if there is reason to believe that the existing pavement is more or less variable than usual.

   DARWIN provides an overlay design methods based upon deflection analysis and back calculation. Other mechanistic based design and back calculation programs are also available. The thickness of the full depth asphalt needed to sustain the design traffic is found by processing the deflection data through the computer program. The required overlay thickness can then be computed from the following formula:

$$TO = TD - TE \qquad \text{Equation 6.4(5)}$$

   where:

   T_O = Overlay thickness
   T_D = Design thickness for new pavement
   T_E = Equivalent existing pavement thickness

6.4.4.3 Pavement Rehabilitation Design Other Than Overlay

The following are some of the major rehabilitation methods used as non-overlay techniques:

- full-depth repair,
- partial-depth patching,
- crack sealing,
- subsealing,
- milling,
- wedge and leveling,
- subdrainage,
- surface treatments, and recycling.

Descriptions of these methods can be found in the AASHTO *Guide for Design of Pavement Structures* 1993, FHWA *Pavement Rehabilitation Manual* and numerous Asphalt Institute publications dealing with specific techniques. Forms 6.4-P, 6.4-Q and 6.4-R may be used to collect and document pavement distress.

6.4.5 Material Sources

The analysis of potential material sources often presents unusual and site-specific problems that require coordination with environmental planning sections as well as the project designer. Detailed investigations are sometimes limited by access and/or lack of detailed site information. A concentrated effort should be made to fully investigate and analyze each material source. Excavation with backhoe and/or core (auger) borings should outline boundaries of the proposed source and should extend at least 3 m (10 ft) beyond the expected floor elevation of the source. The remainder of the source should then be proven out by additional borings and/or excavations.

For typical FLH projects, four to six bore holes and two to four complete sets of aggregate quality tests are required.

The total quantity of materials available from all material sources provided for a specific project should be 10 to 20 percent in excess of the project needs. A material source investigation should provide the following minimum information:

- expected quality of processed materials and procedures necessary to obtain that quality;
- the boundary limits of proven materials and limits of previously used areas;
- specific areas and elevation of nonusable materials;
- previous uses of material from the source;
- recommendations on uses and limitations for processed materials; and
- listing of potential development, processing and handling problems that may occur during construction.

The following provides the basic procedural steps, initial source of reference material and standard forms for a typical material source investigation. Commercial sources do not normally require an investigation.

1. **Initiate Project**. The following applies:
    - Identify available preliminary information (see Exhibit 6.3-A).
    - Review local permit requirements.
2. **Review Available Geotechnical Data**. The following applies:
    - Review previous material source geotechnical reports in vicinity of proposed project.

- Review published information (see Exhibit 6.3-C) with emphasis on geological surveys.

- Identify locations of existing commercial sources in the vicinity.

- Obtain survey contour map and/or site specific cross sections.

3. **Plan Field Investigation**. The following applies:

   - Determine drilling requirements (see Exhibit 6.3-E).

   - Review checklists for site investigations (Form 6.4-H) and material source investigation (Form 6.4-T) to identify information to be collected.

   - Determine preliminary equipment requirements (see Exhibits 6.3-B, 6.3-D and 6.3-L).

   - Determine site restrictions and revise equipment requirements. A site visit may be required.

   - Develop a Preliminary Boring and Testing Plan (see Form 6.3-B).

4. **Plan Sampling and Testing**. The following applies:

   - Determine sampling and testing requirements (see Exhibits 6.3-E, 6.3-G and 6.3-U).

   - Record field information (Form 6.3-C, 6.4-C, 6.4-D, 6.4-H and 6.4-K through 6.4-R, as applicable).

5. **Summarize Field Data**. The following applies:

   - Summarize soils and boring data, as appropriate (Exhibit 6.4-B).

6. **Perform analysis and write report**. The following applies:

   - Review the Material Source Investigation Checklist (Form 6.4-T) to ensure all appropriate information is available.

   - Write draft report. See Section 6.6.

   - Refer to the General Report Checklist (Form 6.4-G) and the Site Investigation Checklist (Form 6.4-H) to ensure appropriate report content.

   - Finalize report.

Material Investigation Checklist

Project: ______________________________

Location: ______________________________

Prepared by: ____________________ **Date:** ____________________

Components	Check Appropriate Box		
	Yes	**No**	**Not Applicable**
1. Is material site location (include description of existing or proposed access routes, bridge load limits, etc.) identified?			
2. Have representative samples of materials encountered during the investigation been tested?			
3. Are laboratory quality rest results included in the report?			
4. Aggregate sources.			
a. Do the laboratory quality test results (e.g., LA abrasion, sodium sulfate, degradation, absorption, reactive aggregate) indicate acceptable materials can be obtained from the deposit using normal processing methods?			
b. If acceptable material cannot be obtained from the source using normal processing methods, have special requirements been provided for processing or controlling production?			
5. Borrow sources, have possible difficulties (e.g., above optimum moisture content clay-silt soils, waste due to high PI, boulders) been noted?			
6. Where high moisture content clay-silt soils must be used, are recommendations provided on the need for aeration to allow the materials to dry out sufficiently to meet compaction requirements?			
7. Has previous use of proposed source been discussed?			
8. Does estimated quantity of proven material satisfy the estimated project needs?			
9. Where materials will be excavated from below the water table, has seasonal fluctuation of the water table been determined?			

Form 6.4-T SAMPLE OF MATERIAL SOURCE INVESTIGATION CHECKLIST

Material Investigation Checklist (continued)

	Check Appropriate Box		
	Yes	**No**	**Not Applicable**
12. Has a material site sketch (plan and profile) been provided for inclusion in the plans, which contains:			
• Material site number or identification?			
• Owner identified?			
• North arrow and legal subdivision?			
• Test hole or test pit logs, location, number and date?			
• Water table elevation and date?			
• Depths of unsuitable layers including overburden which are not acceptable.			
• Potential disposal areas?			
• Potential mining area and previously mined areas?			
• Existing stockpile locations?			
• Existing or potential access roads?			
• Bridge load limits?			
• Reclamation details?			
13. Are recommended contract provisions provided?			

Comments ____

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Form 6.4-T SAMPLE OF MATERIAL SOURCE INVESTIGATION CHECKLIST
(Continued)